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Mountain Pine Beetle Program

FORECASTING MPB OVERWINTERING MORTALITY IN A VARIABLE ENVIRONMENT

Progress Report 2006/2007

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Abstract

We seek to develop and validate a simulation model of mountain pine beetle overwintering mortality. Overwintering mortality is a critical unknown that is temperature- and phenology-dependent and is therefore highly variable in time and space (Bentz & Mullins 1999). It is one factor that we know can reshape a beetle risk map overnight (Safranyik & Linton 1991) and it is a major factor thought to be taken out of play by late 20th century climate warming (Carroll et al. 2004). And yet despite its importance in population trend forecasting, we currently have no capacity for computing changing MPB risk as a function of daily temperature fluctuations. Preliminary work based on U.S. data suggests a valid model of this complex, temperature-dependent process may be possible (Régnière & Bentz 2007).

We seek to extend this work to Canada, by bringing overwintering MPB from the field back to the lab, where we will measure their feeding status and supercooling points and determine their cold tolerance levels. This will be done at periodic intervals throughout the overwintering period so that we can relate changes in cold tolerance levels through time to fluctuations in daily temperature, which are thought to drive the various processes involved, including denucleation (voiding of the gut), and the dynamic synthesis & breakdown of cryoprotectants. Our model will serve as a decision-support tool for clients such as Alberta Sustainable Resource Development, to help them decide months in advance how much labour and capital to set aside for their annual tree-level cut-and-burn MPB control program. It will also assist long-term strategic planning in all jurisdictions in terms of providing a credible assessment of increased MPB risk under winter climate warming.

Year one of this two-year study revealed a very high rate of over-wintering mortality in northern Alberta, as predicted by the unadjusted Régnière-Bentz model. The model's daily output suggested that almost all of this mortality happened during an anomalously early cold snap November 26-28, when daily minimum temperatures across the province dropped suddenly from ~0°C to a winter low between -32 and -38°C. Additional data collection in year two will focus on obtaining parameters to customize the model for use in Alberta.

Keywords: overwintering mortality, cold tolerance, winterkill, biometeorology, risk analysis

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1 Introduction

Overwintering mortality is such a large part of MPB generation mortality (and hence population trend) that the province of BC estimates it annually in every district where MPB occurs. For the last few years overwintering mortality in BC has averaged ~50%, which is considered relatively low, favouring rapid population increase. The idea for this project began when Alberta Sustainable Resource Development (ASRD) Forest Health contacted CFS about a possible discrepancy between observed rates of MPB winter mortality in Alberta as compared to BC. Specifically, mortality rates seemed much higher and more variable in Alberta than BC. ASRD wanted to know if these regional differences in overwintering mortality rates were significant and whether they could be accounted for by regional weather effects alone (including the effects of topography and phenology), or if some other factor (e.g. genetics or host-plant effects) must be implicated. The Alberta observations were considered noteworthy because the data ran contrary to: (1) the expectation of higher MPB cold-tolerance in AB than BC, and (2) the observed rapid rate of MPB population increase in AB.

If regional differences in overwintering mortality rates could be accounted for by regional weather effects alone, then we reason that it should be possible to predict overwintering mortality on an ongoing daily basis as a function of daily weather fluctuations. Not only would this help clarify any discrepancies between the BC and AB mortality surveys, it would reduce the reliance on these expensive surveys, and it would also provide a basis for planning the following summer's monitoring and control activities.

MPB winter-kill is inherently difficult to predict because (1) cold tolerance is a highly dynamic physiological attribute; (2) weather is a highly random variable at the daily time-scale; (3) MPB phenology is highly idiosyncratic (because it does not diapause, the life cycle runs freely, which means that populations can have mixed ages, including eggs, larvae pupae, and adults, each of which may have a different baseline level of cold tolerance); (4) microclimates vary (due to factors such as slope, aspect, exposure to sun, and snow depth), (5) topography in large landscapes is complex. For this reason it is necessary to use sophisticated computer-based models for simulating MPB phenology and over-wintering survival.

The absence of a cold-tolerance module in the Safranyik et al. (1999) population model attests to the fact that our knowledge in this area is inadequate. If we want to forecast winterkill on a daily or weekly basis, we need to develop good process-based models that operate on a daily time step.

2 Project Objectives and Progress

2.1 Overview

Table 1. Overview of project progress in 2006/2007.

Deliverables	Progress
Project description on website	Done
Establishment of field plot and sample tree locations	Done
Set-up of cold-tolerance testing facility	20% complete
Workshop presentation (ASRD IFPM) "MPB in Alberta: Development of modern, process-based risk analysis tools"	Done
Submit paper: Modeling cold resistance in the mountain pine beetle	Done (now published)
Two presentations, in addition to those promised	Done

2.2 Project Objectives

Our objective is to be able to forecast, real-time, the degree of MPB winter-kill across a variable landscape as a function of daily temperature fluctuations. From early work by Safranyik & others we know that MPB are somewhat cold tolerant. Because of their ability to supercool, temperatures must drop to -30°C to -40°C or lower in order to kill overwintering beetle larvae in mid winter. However, there are four major challenges that still need to be overcome before this qualitative insight can be translated into a robust, quantitative, predictive tool:

(1) we need to know the precise relationship between temperature and overwintering survival, expressed in terms of the physiological processes influencing cold tolerance;
(2) we need to know this for all beetle life stages (pupae, adults, eggs, all three larval states), and not just the state III (i.e. the ultra cold-tolerant) larvae;
(3) we need to be able to accurately forecast MPB population age structure (proportion of life stages) at all locations in the landscape, considering variable elevation, slope, aspect;
(4) we need a software platform for integrating these data in the form of a usable winter-kill 'calculator'.

3 Dissemination of Results

3.1 Papers Written

Régnière, J. and B. Bentz. 2007. Modeling cold tolerance in the mountain pine beetle, *Dendroctonus ponderosae*. *J. Insect Physiol.* 53: 559-72.

Cooke, B.J., Régnière, J. and B. Bentz. Validative test of a model of mountain pine beetle (Dendroctonus ponderosae Hopk.) overwintering mortality resulting from exposure to cold temperatures. [To be submitted to *Environmental Entomology*]

3.2 Presentations/Conferences

Cooke, B.J., J. Régnière, B. Bentz. 2007. Modeling mountain pine beetle cold-tolerance and overwintering mortality across Alberta. Alberta-British Columbia Forest Health Workshop. Hinton, AB, April 17.

Cooke, B.J., J. Régnière, B. Bentz. 2007. Modeling mountain pine beetle cold-tolerance and overwintering mortality across Alberta. MPBI Information Session. Grande Prairie, AB, May 10.

4 2007/2008 Project Work Plan

Table 2. Overview of project activities planned for 2007/2008.

Activity	Progress
Set up cold tolerance lab	ongoing
Publish model validation paper	50% complete
Obtain experimental data on survivorship among instars	To be done
Tune model	To be done
Write second paper on finalized model	To be done

5 Contribution of Research Group Members

Two research teams made invaluable intellectual contributions to laboratory design, model development and model validation:

- B. Bentz and J. Vandygriff, USDA-FS, Logan, UT: 0.05 FTE
- J. Régnière and R. St.-Amant, Laurentian Forestry Centre, Ste-Foy, QC: 0.1 FTE

6 Collaboration with Partners

Alberta Sustainable Resource Development provided several in-kind contributions, valued at a total of roughly $500 000:

- access to ground survey data for MPB infested trees (GPS point locations)
- access to winter survival data from over 123 locations from across Alberta

• access to provincially maintained weather station data (14 stations)
• ~16 hours of helicopter time (used for sampling in remote areas)

7 Problems Encountered

No problems were encountered, although two random events served to strongly re-shape the research program described in the original Project Outline. First, an invasive flight of beetles beyond the Grande Prairie region (as far as Peace River to the Northwest and Fox Creek to the Southeast) meant that there were source populations in areas other than Kakwa Wilderness Park and Banff National Park that could be studied. Second, the fortuitous extreme cold temperatures that killed mountain pine beetle in late November presented us with a rare opportunity to precisely measure overwintering mortality across a gradient of landscape conditions. For this reason we chose in year one to focus more on model validation (predicted vs. observed mortality across the province) and less on laboratory experimentation. This variance is reflected in faster-than-expected progress on model validation (Table 2) and lower-than-expected equipment expenditures for 2006/07 (Table 3).

8 Financial Summary

Table 3. Overview of projected and actual costs for 2006/2007.

	Annual Total	Annual Budget	Variance
Salaries & stipends	$31,000.00	$31,000.00	$0.00
Employee benefits	$3,000.00	$3,000.00	$0.00
Equipment	$10,000.00	$56,000.00	$46,000.00
Travel[1]	$18,000.00	$23,000.00	$5,000.00
Material & supplies	$3,000.00	$3,000.00	$0.00
Other - Please specify	$0.00	$0.00	$0.00
Sub Total	$65,000.00	$116,000.00	$51,000.00
Administration costs	$0.00	$0.00	$0.00
Totals	$65,000.00	$116,000.00	$51,000.00

[1] field travel and accomodations

9 Acknowledgements

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10 Appendices

The following unpublished scientific report is available upon request:

Cooke, B.J., Régnière, J. and B. Bentz. Validative test of a model of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) overwintering mortality resulting from exposure to cold temperatures.